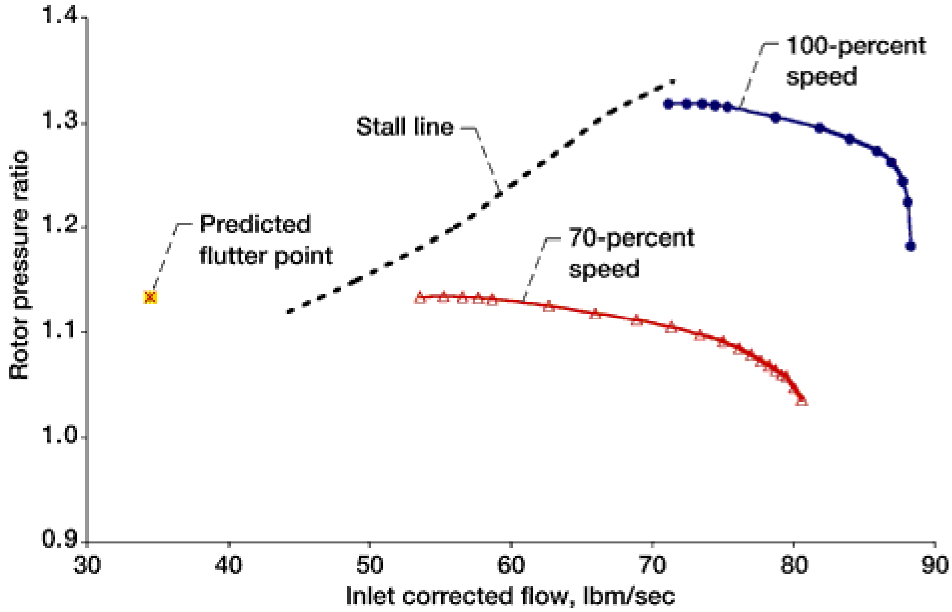
Flutter Stability of the Efficient Low Noise Fan Calculated

The TURBO-AE aeroelastic code has been used to verify the flutter stability of the Efficient Low Noise Fan (ELNF), which is also referred to as the trailing-edge blowing fan. The ELNF is a unique technology demonstrator being designed and fabricated at the NASA Glenn Research Center for testing in Glenn's 9- by 15-Foot Low-Speed Wind Tunnel. In the ELNF, air can be blown out of slots near the trailing edges of the fan blades to fill in the wakes downstream of the rotating blades. This filling of the wakes leads to a reduction of the rotor-stator interaction (tone) noise that results from the interaction of wakes with the downstream stators. The ELNF will demonstrate a 1.6-EPNdB[1] reduction in tone noise through wake filling, without increasing the broadband noise. Furthermore, the reduced blade row interaction will decrease the possibility of forced response and enable closer spacing of blade rows, thus reducing engine length and weight.

During the design of the ELNF, the rotor blades were checked for flutter stability using the detailed aeroelastic analysis capability of the three-dimensional Navier-Stokes TURBO-AE code. The aeroelastic calculations were preceded by steady calculations in which the blades were not allowed to vibrate. For each rotational speed, as the back-pressure was increased, the mass flow rate decreased, and the operating point moved along the constant-speed characteristic (speed-line) from choke to stall as shown on the fan map.

The TURBO-AE aeroelastic analyses were performed separately for the first two vibration modes (bending and torsion) and covered the complete range of interblade phase angles or nodal diameters at which flutter can occur. The results indicated that the ELNF blades would not encounter flutter at takeoff conditions. The calculations were then repeated for a part-speed condition (70-percent rotational speed), and the results again showed no flutter in the operating region. On the fan map (shown), the predicted flutter point at part-speed condition was located beyond the stall line, which means that the ELNF will not encounter flutter since it will never operate beyond the stall line. All the calculations done so far have been for the nonblowing case, and selected calculations will be repeated with air blowing from the trailing edge of the fan.



Fan map for the Efficient Low Noise Fan (ELNF) showing constant-speed characteristics, or speed lines, and the flutter point calculated using the TURBO-AE aeroelastic analysis code.

Long description. The fan map is a plot of the rotor pressure ratio versus the mass flow rate. The constant-speed characteristics, or speed lines, for 100- and 70-percent rotational speeds are shown. The calculated flutter point at the 70-percent rotational speed is seen to fall beyond the stall line, indicating that there will be no flutter in the operating region.

The completion of the TURBO-AE flutter calculations for the ELNF with trailing edge blowing will verify that there will not be unexpected flutter problems during wind tunnel testing of this unique technology demonstrator. The aeroelastic calculations described here were performed under a contract by University of Toledo researchers in collaboration with Glenn researchers. This work was supported by the Quiet Aircraft Technology Project and the Ultra-Efficient Engine Technology Project.

[1]Effective perceived noise level.

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